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THE NEW METALLURGICAL EXPERIMENT STATION FOR THE BUREAU OF MINES, UNITED STATES DEPARTMENT OF THE INTERIOR, AT SALT LAKE CITY, UTAH

BY

R. S. DEAN AND CRESAP MOSS

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

THE NEW METALLURGICAL EXPERIMENT STATION FOR THE BUREAU OF MINES, UNITED STATES DEPARTMENT OF THE INTERIOR, AT SALT LAKE CITY, UTAH1/

By R. S. Dean2/ and Cresap Moss3/

INTRODUCTION

A large metallurgical experiment station at Salt Lake City to house the work of the Bureau of Mines in the intermountain area properly has long been projected. It finally became possible when a Public Works Allotment of $300,000 was set aside for building and equipment. With the new building assured, the Bureau of Mines decided to move the headquarters of its Metallurgical Division from Washington, D. C., to Salt Lake City, Utah. It was felt that this move would simplify the administrative work of the chief engineer of the division, as all stations devoted primarily to metallurgical work are west of the Mississippi River. These include Rolla, Mo.; Minneapolis, Minn.; Pullman, Wash.; Reno, Nev.; Berkeley, Calif.; Boulder City, Nev.; and Tucson, Ariz. In addition to these stations small groups of investigators working on metallurgical problems are maintained at Pittsburgh, Pa., and College Park, Md. Salt Lake City was clearly a more central point for the direction of this scattered work than Washington, D. C.

The building (fig. 1, A and B) was designed from general plans worked out by the authors of this paper. Construction was begun in March of 1939, and by the end of the year the Metallurgical Division had moved into its new quarters.

A building was required to furnish adequate office space for the administrative work of the Metallurgical Division and for the resident groups of the Safety and Mining Divisions; small laboratories for chemical, physical, and microscopic experiments; and large laboratories for metallurgical and ore-dressing experiments.

1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7116."

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It was not possible to accomplish this in a single building of uniform construction throughout. Accordingly, the building was designed in two unit a three-story unit for offices and small laboratories (fig.2) and a single-story, monitor-roof, shop-type unit for the large laboratories (fig.3).

The buildings are situated near the center of a 4-acre tract of land deeded to the United States Government by the University of Utah and extending directly east of the University campus and adjacent to the grounds of Fort Douglas.

Both buildings are of virtually fireproof construction, the material used being steel, concrete, and brick. The design of both buildings is as simple as possible in order that the highest degree of flexibility might be obtained. All pipe lines and electrical conduits are in tunnels and shafts beneath the buildings, where they are readily and easily accessible for changes and additions (fig. 14,B). There are both underground and surface connecting passageways between the building units. In the underground passageways are the steam, water, gas, and electrical conduits. Within the concrete floors of all laboratories is 2-1/2-inch conduit with outlets on 30-inch centers for electrical service, both alternating and direct current. There is, however, 15 feet difference in elevation between the rear of the one-story laboratory unit and the ground floor of the three-story unit, which places the front of the single-story unit on approximately the second-floor level of the three-story unit.

THREE-STORY UNIT

The three-story unit is 140 by 40 feet in size. The administrative office floor of the three-story unit is the second floor of the building (fig. 2,B,), but is the ground floor as entered from the loading platform between the three-story unit and the single-story unit. From the loading platform a door leads directly to the receiving clerk's desk in the office of the building superintendent so that all shipments can be checked promptly and easily. There are 16 offices on this floor, including the administrative offices of the Metallurgical Division and those of the Mining and Safety Division resident engineers. The Safety Division equipment is also kept in readiness for instant service in a room located on this floor (fig.4,A.).

In the center of the top floor of the office building is a library, 36 by 15 feet. It has on file the more important technical journals and most of the recent books on metallurgy, including approximately 2,000 volumes.

At the north end of the top floor are the physical laboratories. Particular attention has been given by the division to application of modern physi to the solution of metallurgical problems, and these laboratories reflect thi emphasis in their unusual and highly specialized equipment, much of which has been designed by the Bureau's own experts. Especially comprehensive is the apparatus available here for the generation of high-frequency sound waves and the measurement of their intensity, velocity, and wave form. The division has found that sound waves having a frequency just beyond those that affect the human ear (and therefore are termed "supersonic") perform many operations

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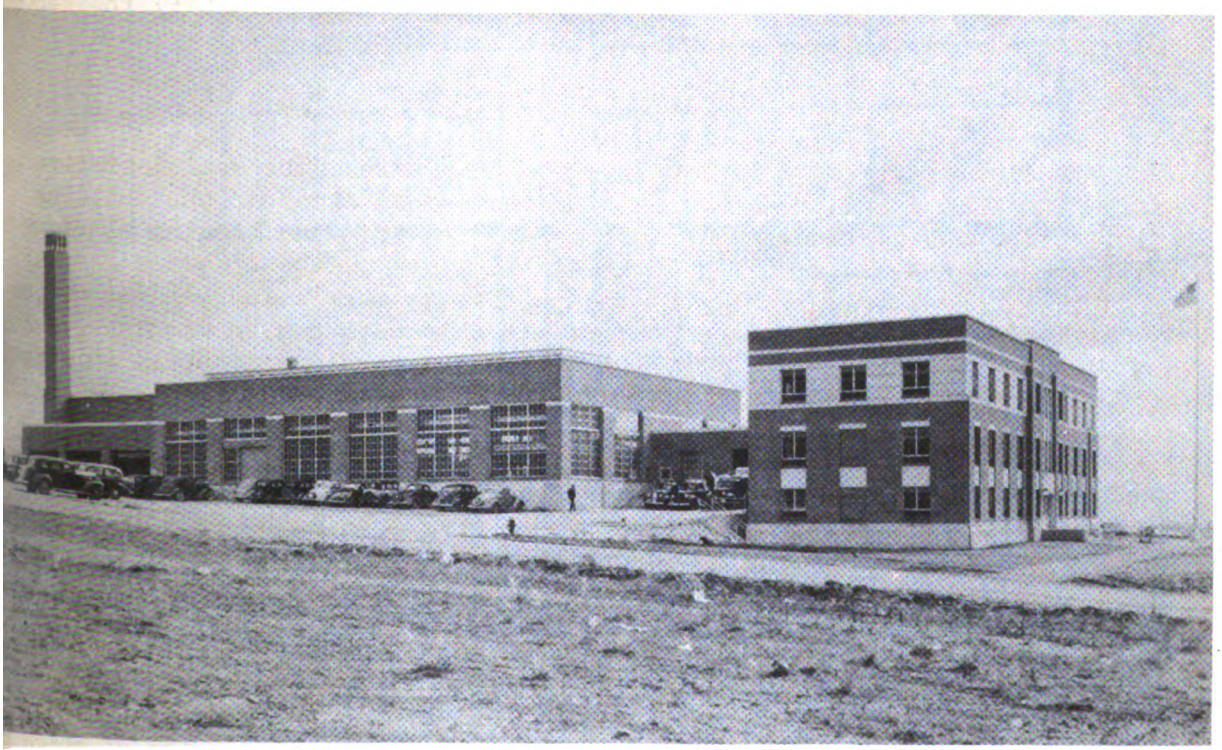

B

Figure 1.- A, Front view of building; B, Side view of building.

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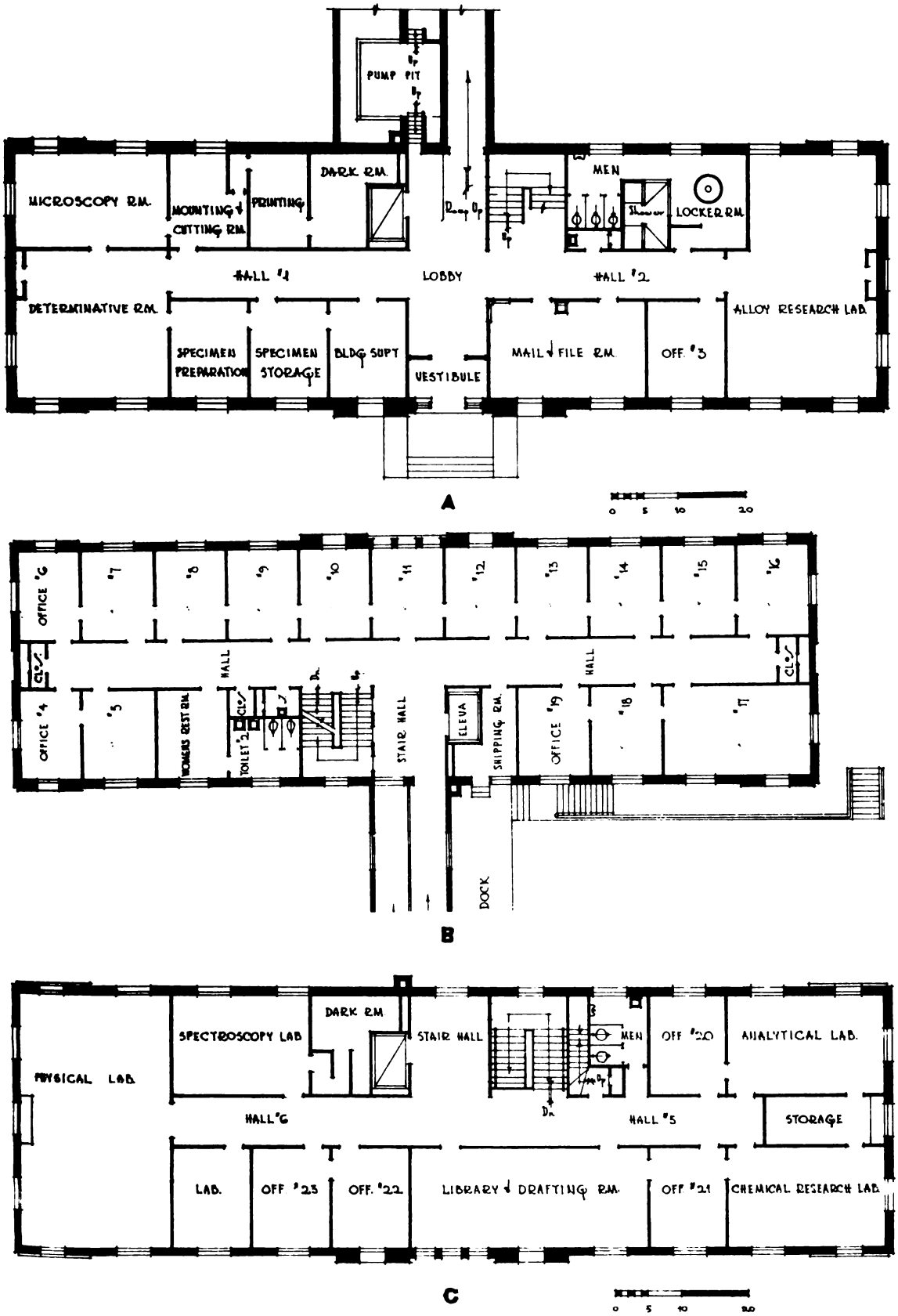

Figure 2.- Plans of offices: A, Ground-floor plan; B, floor 1; C, floor 2.

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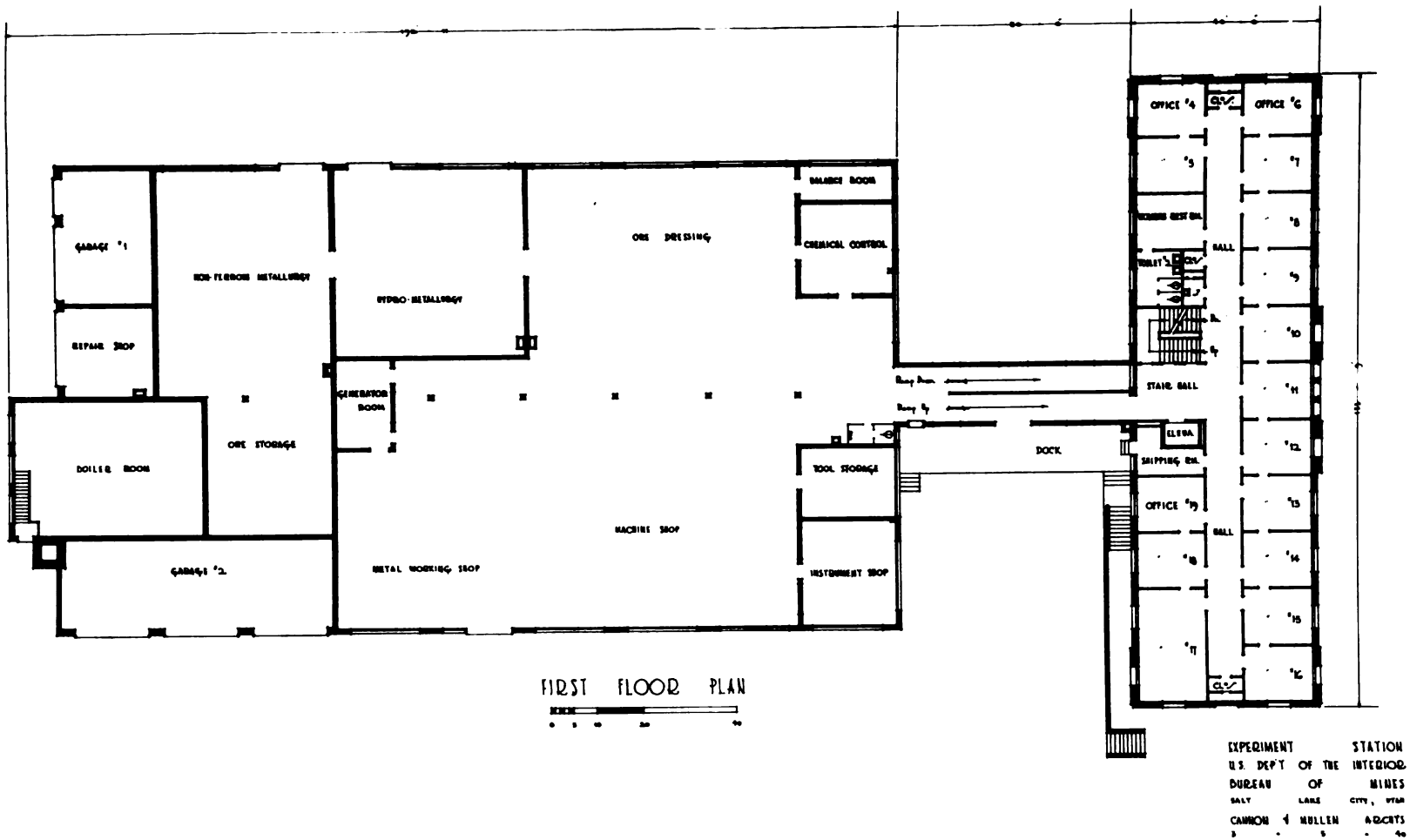

Figure 3.- Floor plan of single-story unit and offices.

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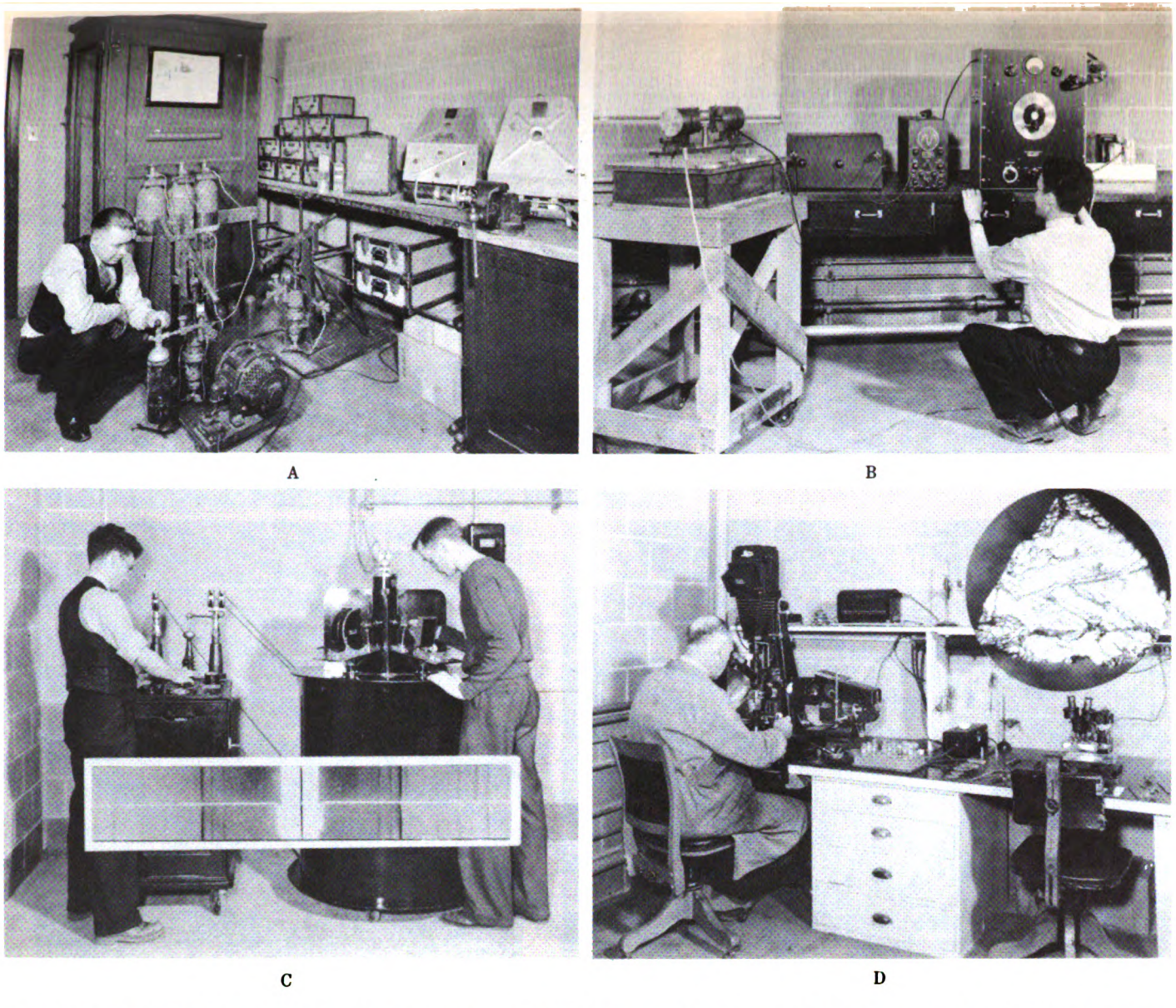

A B C D

Figure 4.- A, Safety Division equipment is kept in readiness for instant service; B, the cathode-ray oscillograph is used to make visible vibrating forms of metals; C, X-rays when reflected from metal and mineral surfaces give definite patterns; D, a specially equipped microscope permits visual observation and photomicrography.

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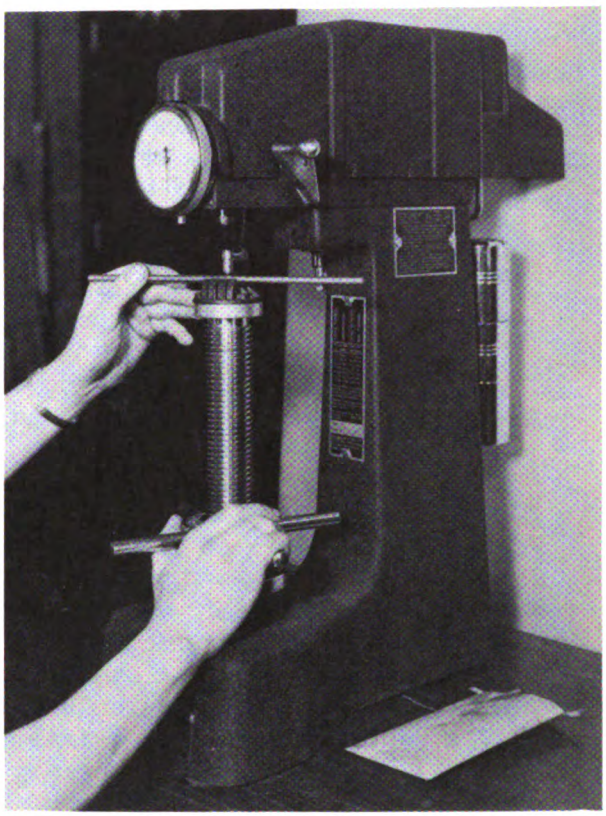

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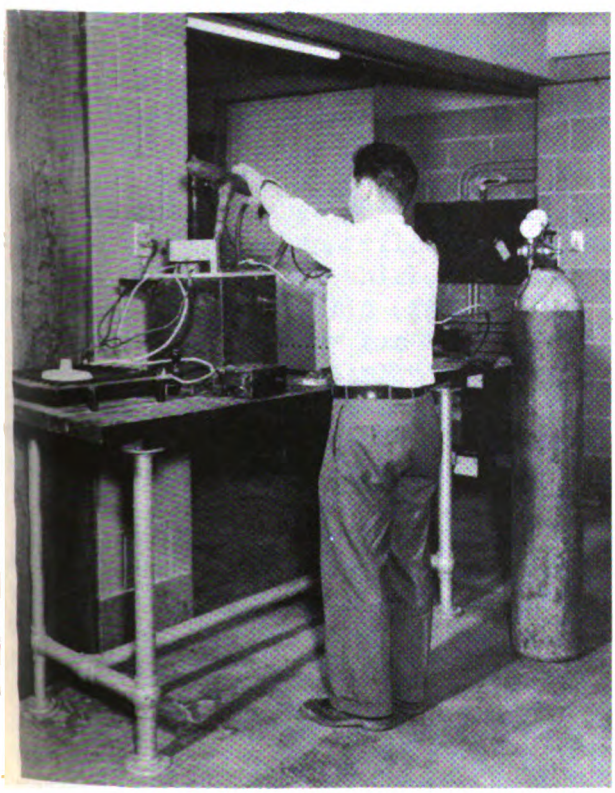

C

D

Figure 5.- A, Sound generators, including the newly devised type which it is hoped will make sound precipitation of smoke a useful reality; B, a hardness tester that measures hardness by forcing a diamond into all but the hardest metal; C, melting and casting magnesium under helium; D, a tiny induction furnace capable of melting a thimbleful of metal.

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aluable to metallurgists, not the least of these being the precipitation f smoke and fog. Here are innumerable kinds of sound generators, in- ding a newly devised type, which it is hoped will make sound precipi- ation of smoke a useful reality (fig. 5,A).

Oscillographs are instruments that show the frequency and form of lectrical or sound waves (fig. 4,B). Apparatus of this type includes the lder Einthoven string oscillograph, which depends on the vibrations of a iny copper thread in a powerful magnetic field and the newer cathode-ray scillographs in which the eye of the modern television apparatus is used o make visible vibratory forms of air and metal. One such oscillograph s used regularly to measure noise absorption by metal gears and machine arts. A new nonferrous alloy gives promise of greatly reducing racket in his troubled world, and in the division's physical laboratory is found quipment for accurately measuring the ring of a metal. You couldn't pass a lead quarter here!

Aside from this highly specialized equipment, the physical laboratory has bridges and potentiometer circuits for measuring electrical resistance and the thermoelectric force of metals. These measurements are of direct value in determining the possibilities of new alloys like those of magnesium in the electrical industries. They are, furthermore, of great help to metal- lurgists in interpreting alloy structures. There is also equipment for measuring coefficient of expansion, modulus of elasticity, magnetic proper- ties, and almost any physical property of matter that metallurgists may need to know in solving problems leading to a greater use and service of metals to mankind.

Next to the large physical laboratory is a laboratory for X-ray spect- roscopy. X-rays, when reflected from metal and mineral surfaces, give definite patterns from which a skilled metallurgist can tell how the atoms are arranged in the solid (fig. 4,C). Since its introduction only 20 years ago, X-ray spectroscopy has become an indispensable tool in the identifica- tion of minerals and metallurgical products and the unraveling of the structures of slags, metals and mattes. This laboratory is provided with metal X-ray tubes which have been found to be most suitable for this work and cameras for all of the usual types of X-ray spectroscopy.

The south end of the top floor is occupied by the chemical laboratories. An analytical laboratory and a research laboratory are connected by a large store room for chemicals and apparatus. The chemical laboratories have their own water stills and are provided with suitable equipment for analytical and special work.

The north end of the first floor is occupied by the laboratory for ore microscopy (fig. 4,D). The Salt Lake laboratory of the division has been a pioneer in the application of the microscope to ore-dressing problems. Much of the now generally used technique of preparing ore samples for microscopic study was first used by the staff of this laboratory. The laboratory con- tains much mounting and polishing equipment developed and built by the divi- sion. Alongside this highly efficient but homemade apparatus will be found

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the latest machines and instruments. Hand polishing of the tiny specks of mineral mounted in synthetic resins has been in part, at least, replaced by an automatic polishing machine; many difficulties of microscopic examination are obviated by a microscope that permits visual observation and photography in both reflected and transmitted light. For counting mineral grains, a multiple-spindle integrating stage saves much time. This laboratory is equipped with its own dark room, so that the microstructure of minerals may be recorded permanently on photographic plates. Perhaps the most valuable part of this laboratory is its extensive collection of ores and minerals. These are necessary for comparison and study of identification methods for the almost unlimited number of mineral species which come to the metallurgist for treatment.

On the south end of the first floor are the alloy laboratory and metallographic laboratory. The development of new alloys and metal compounds is the most promising method of increasing the use of metals and therewith, of course, more efficient utilization of our mineral wealth. Such new combinations when conceived in the minds of metallurgists must at first be made on a small scale under rigidly controlled conditions and their properties and structure carefully studied. For this purpose the laboratory has a tiny induction furnace (fig. 5,D) capable of melting quickly and without contamination a thimbleful or so of even the most refractory metals, like platinum. Here countless alloys are made, many of which may be discarded by the simple test of hammer and anvil, because, after all, a metal must first be strong and tough to have much use. Small rolling equipment is available to make rods and strips of tiny ingots.

The alloys found to be workable must be tested for hardness and strength and there is in this laboratory a hardness tester which measures hardness by forcing a diamond into all but the hardest metals (fig. 5,B). Where the hard is too great for indenting with a diamond point the material may still be scratched, and the width of such a scratch made with a specially shaped and weighted diamond is the basis of hardness measurement by means of the microcharacter, another hardness testing machine available in this laboratory. A hydraulic testing machine measures the strength and toughness of rods and wires.

Like the other laboratories, this has its specially made equipment. Among such equipment may be mentioned a furnace for melting and casting magnesium and its alloys under helium (fig. 5,C), since only in this rare gas can magnesium be melted without contamination. In connection with the alloy laboratory is a completely equipped metallographic unit. This serves to determine the structure of metals and alloys as revealed by microscopic examination of suitably etched surfaces (fig. 6). Preparation of such surfaces requires the greatest care, and polishing wheels must be carefully protected from dust. Once the specimen is suitably prepared it is examined on a micrometallograph, the latest type of instrument constructed especially for examination of metals. Excellent photographs of metal structure up to magnifications of 2,000 diameters may be prepared with this instrument.

All of the laboratories are provided with steel laboratory benches and acidproof sinks. The office furniture used in the laboratories is also of

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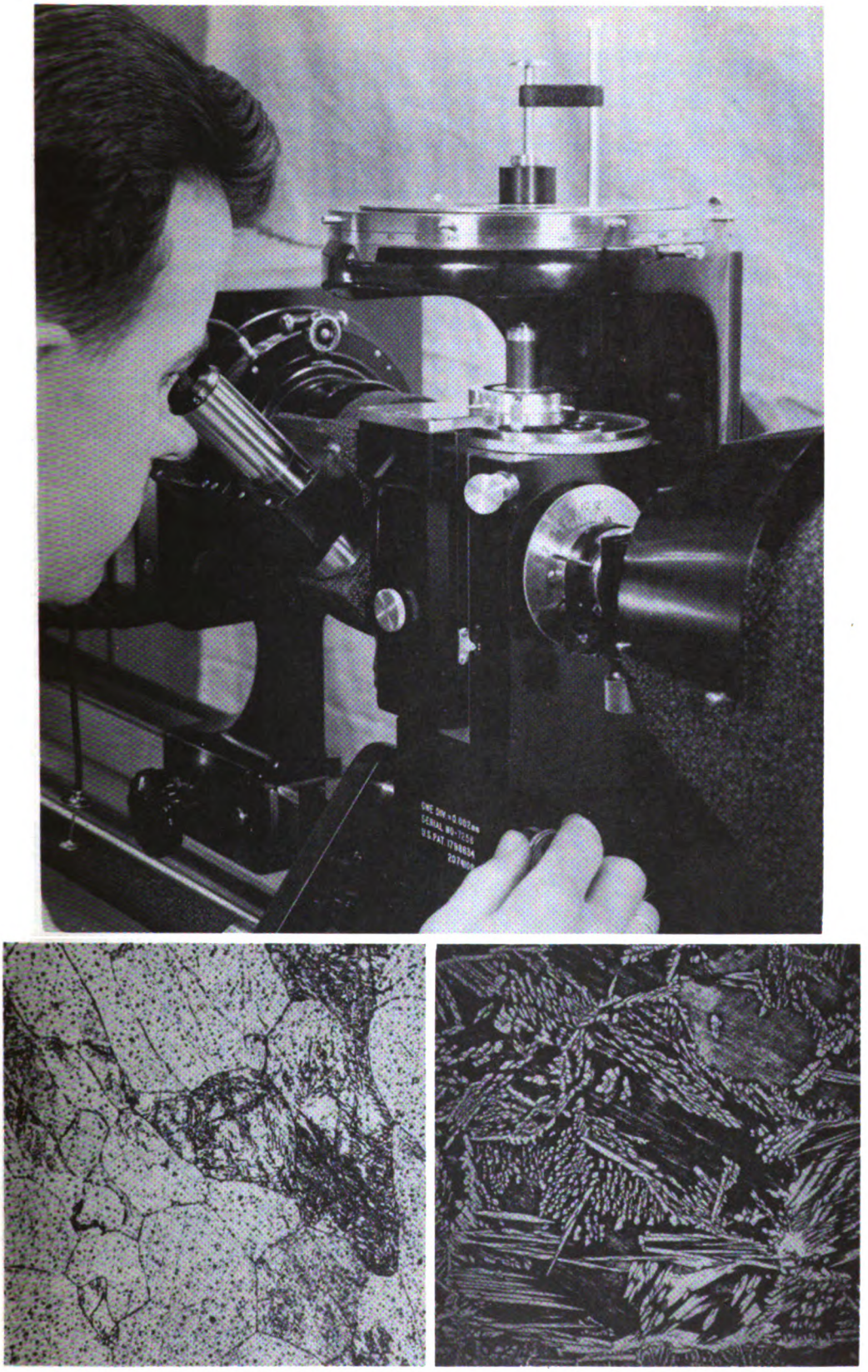

Figure 6.- The structure of metals and alloys as revealed by microscopic examination.

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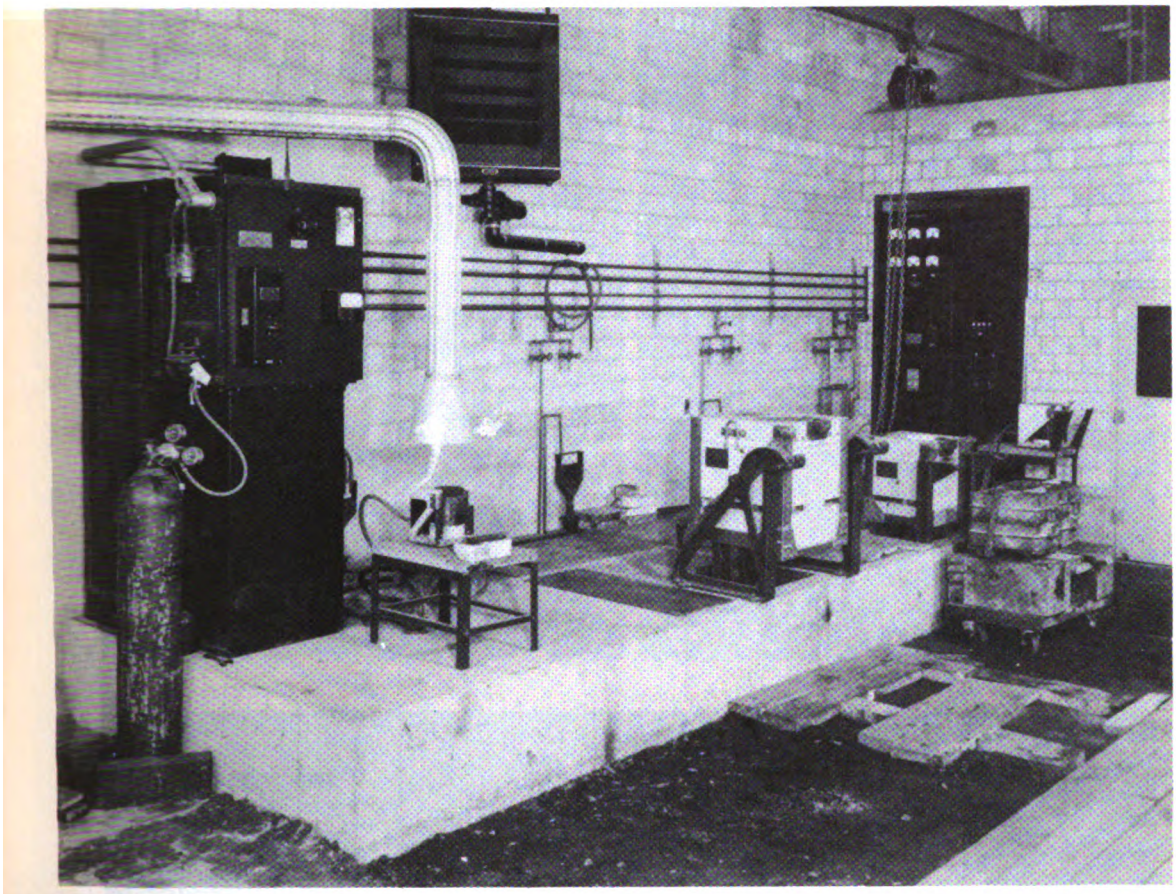

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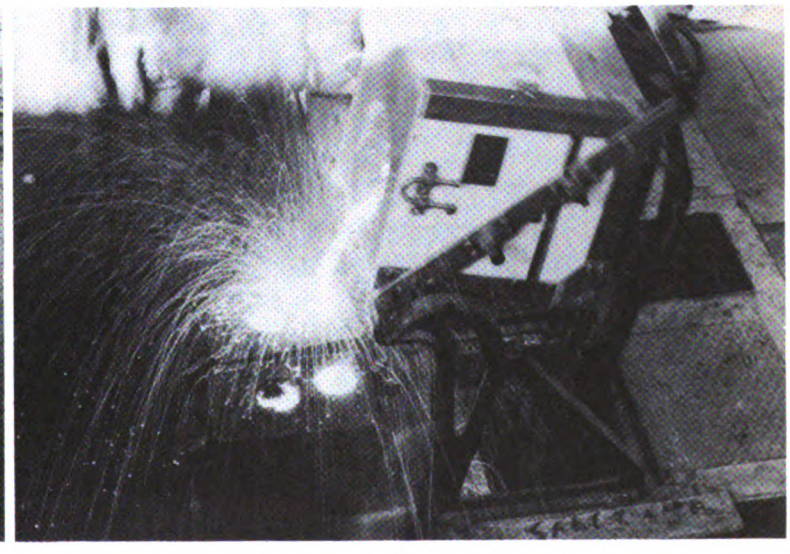

C

Figure 7.- A, The melting equipment is unusually complete; B, C, induction furnaces are also ideal for carrying out smelter reactions on a small scale.

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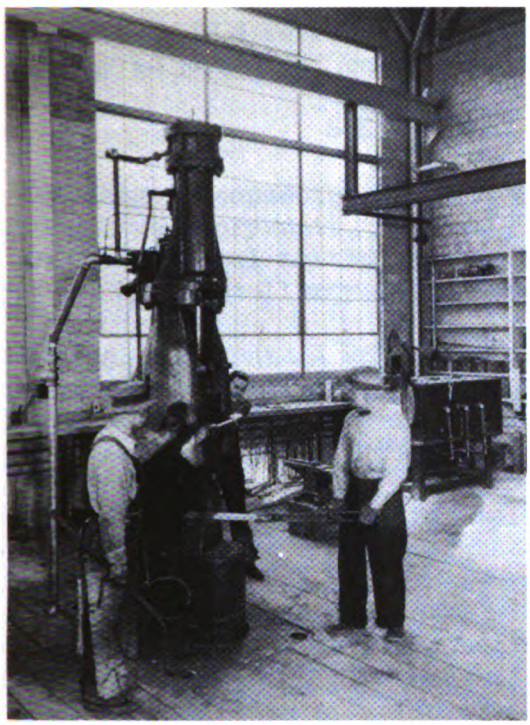

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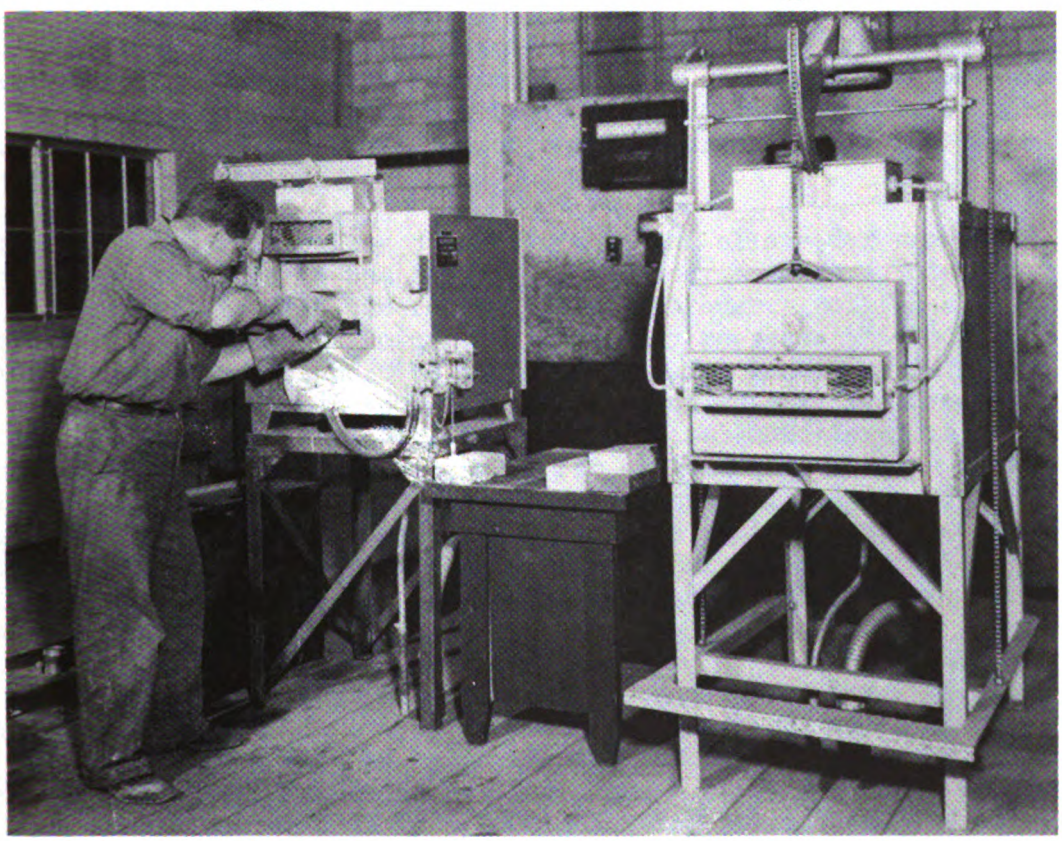

C

Figure 8.- A, A steam hammer capable of striking a 750-pound blow. B, For making small rods a swaging machine is desirable. C, Electric furnaces with automatic temperature control are available in several sizes.

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bel construction. The services are mounted on the wall back of the benches that they may be moved and rearranged with a minimum of effort.

SINGLE-STORY UNIT

This building is connected by 50-foot ramps to the first and second oors of the three-story unit. The single-story unit is divided into four in sections - the metal melting and working laboratory, the ore-dressing boratory, the hydrometallurgy laboratory, and the pyrometallurgy laboratory.

The melting equipment is unusually complete (fig. 7,A). Two high-frequency generators are available for the operation of furnaces, a 35 kv.-a. ercury-gap unit and a 60 kv.-a. 2,000-cycle motor-generator-driven unit. ese furnaces can make melts from 5 to 150 pounds.

Induction furnaces are ideal for melting metals and alloys without contamination. They are also of great value in carrying out smelting reactions n a small scale (fig. 7,B and C), because unlike crucible furnaces heated ith gas or oil, the heat is generated within the metal charge itself, making t possible to have the refractory container cooler than the charge, which s characteristic of all smelting operations as commercially carried out. o provide for the emission of sulfurous and other gases when these furnaces re used to study smelting reactions, they are equipped with hoods. Ingots f metals and alloys cast from these furnaces closely simulate those used or commercial production of strips, bars and sheets. They are large enough o they may be worked down under the hammer exactly as commercial tool-steel ngots. For this purpose there is provided a steam hammer capable of striking 750-pound blow (fig. 8,A). This hammer rapidly forges ingots into shape for urther working or machining.

To determine the suitability of many metals and alloys for practical se, they must be obtained in the form of sheet, rod, or wire. To produce his, it is necessary to pass the forged billets through a rolling mill. If he product of this mill is to be uniform and truly representative of the ommercial product, the mill must be accurate to a few ten-thousandths of an nch and still powerful enough to flatten billets of relatively hard metal. he rolling mill available may therefore seem on first consideration to be ore rugged and powerful than is necessary for experimental work. Careful study, however, showed that this 40-horsepower mechanism, driving rolls 8 inches in diameter and with a 12-inch face, was the minimum size that could be expected to give useful results. This mill is driven by a variable-speed, direct-current motor and can roll squares, rounds, or flats at speeds of 4 to 40 feet per minute.

For making small rods that are accurately round, a swaging machine has been found most desirable (fig. 8,B), especially for experimental work. The swaging operation is performed by hammering the rod between two halves of a revolving die. The swaging machine available has a closely spaced series of dies from 3/4-inch diameter down to 5/100 inch. For still finer rod or wire the metal must be drawn through carboloy dies. Suitable drawing equipment has been provided in the machine shop.

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Some alloys, such as those of magnesium, cannot be fabricated successfully by rolling, swaging, or drawing. They must be extruded (fig. 9,A). For working these alloys an 80,000-pound press and suitable dies are available.

Heat treatment is a vitally important part of any metallurgical laboratory. Electrical furnaces with automatic temperature-control mechanisms are available in several sizes (fig. 8,C). These furnaces include not only the ordinary electrical resistance furnace with an upper temperature limit of 1,800°, but furnaces wound with the new No. 10 alloy which can be operated up to 2,500°.

These furnaces have muffle sizes up to 8 by 12 by 48 inches for the 1,800° furnaces and 6 by 7 by 18 inches for the 2,500° furnaces. In addition to these electric furnaces, several high-pressure, gas-fired furnaces are available.

Special attention has been given to the machine-shop equipment in this laboratory. In a metallurgical laboratory where much of the equipment is of special design, it is important from the standpoint of both time and economy that a machine shop be available that can build fairly large equipment and can also handle instrument and precision work, such as is required continually in the physical and other laboratories. Funds available have not as yet permitted completion of the machine shop. The policy has been followed of installing the more necessary pieces of really good equipment rather than using the same amount of money to completely equip the shop with second-rate machines.

For lathe work there is available an unusually large lathe for a laboratory shop (fig. 9, C and D). This is a geared lathe with a 32-inch swing and a 14-foot bed; it is capable of quite high precision for so large a lathe. For ordinary lathe work there is an engine lathe with a 16-inch swing and a 5-foot bed. A 5-foot radial drill press is capable of performing a great many machining operations with an exceptional degree of precision (fig. 9,B).

This drill press can use No. 63 drills accurately at 1,500 r.p.m. or with equal ease can sink a 5-inch tap in solid steel. It is equipped with numerous arbors and milling cutters with which milling jobs are done. Vertical milling and boring operations are through necessity temporarily done on this machine.

Since at the outset the shop has been called upon to make many special tools, such as extrusion dies, a grinder has been provided. This grinder is used to manufacture parallels and precision equipment for the physical laboratory, as well as precision dies and other special equipment. Cylindrical, surface, and internal grinding of special dies and precision-instrument parts demanding close tolerances is accomplished as easily as ordinary tool and cutter grining. Unusual roll shapes up to 20 inches in diameter may be ground with accuracies up to 0.0001 inch

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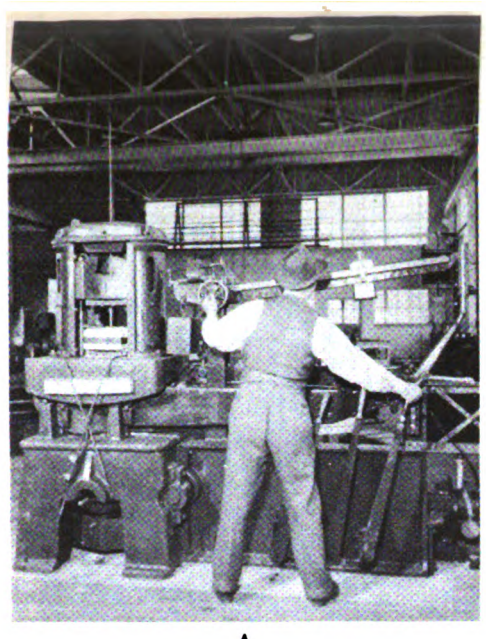

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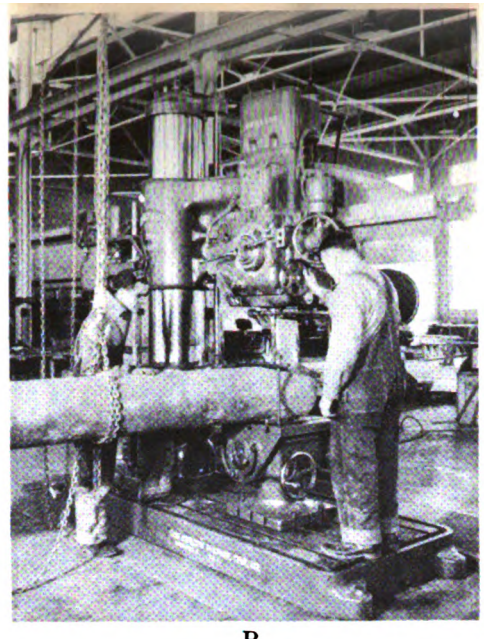

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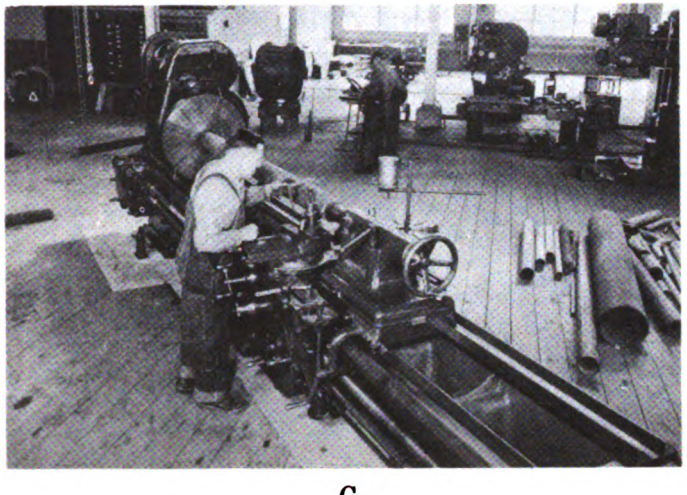

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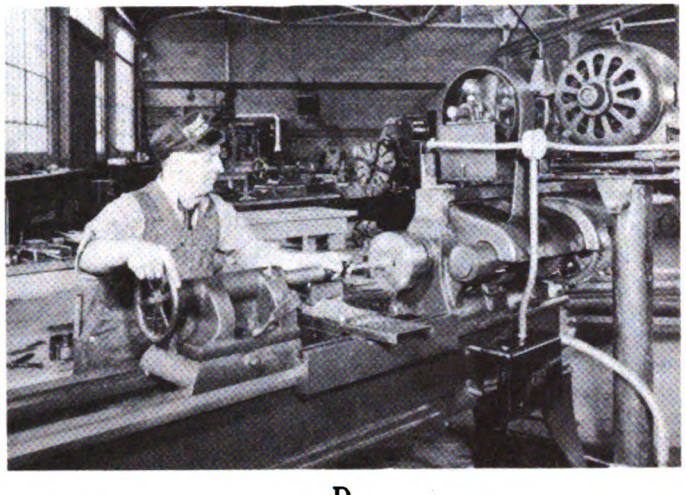

D

Figure 9.- A, Extrusion of magnesium alloys (note the extruded rod); B, a 5-foot radial drill makes a No. 63 hole or a 5-inch hole with precision; C, D, an unusually large lathe for a laboratory shop.

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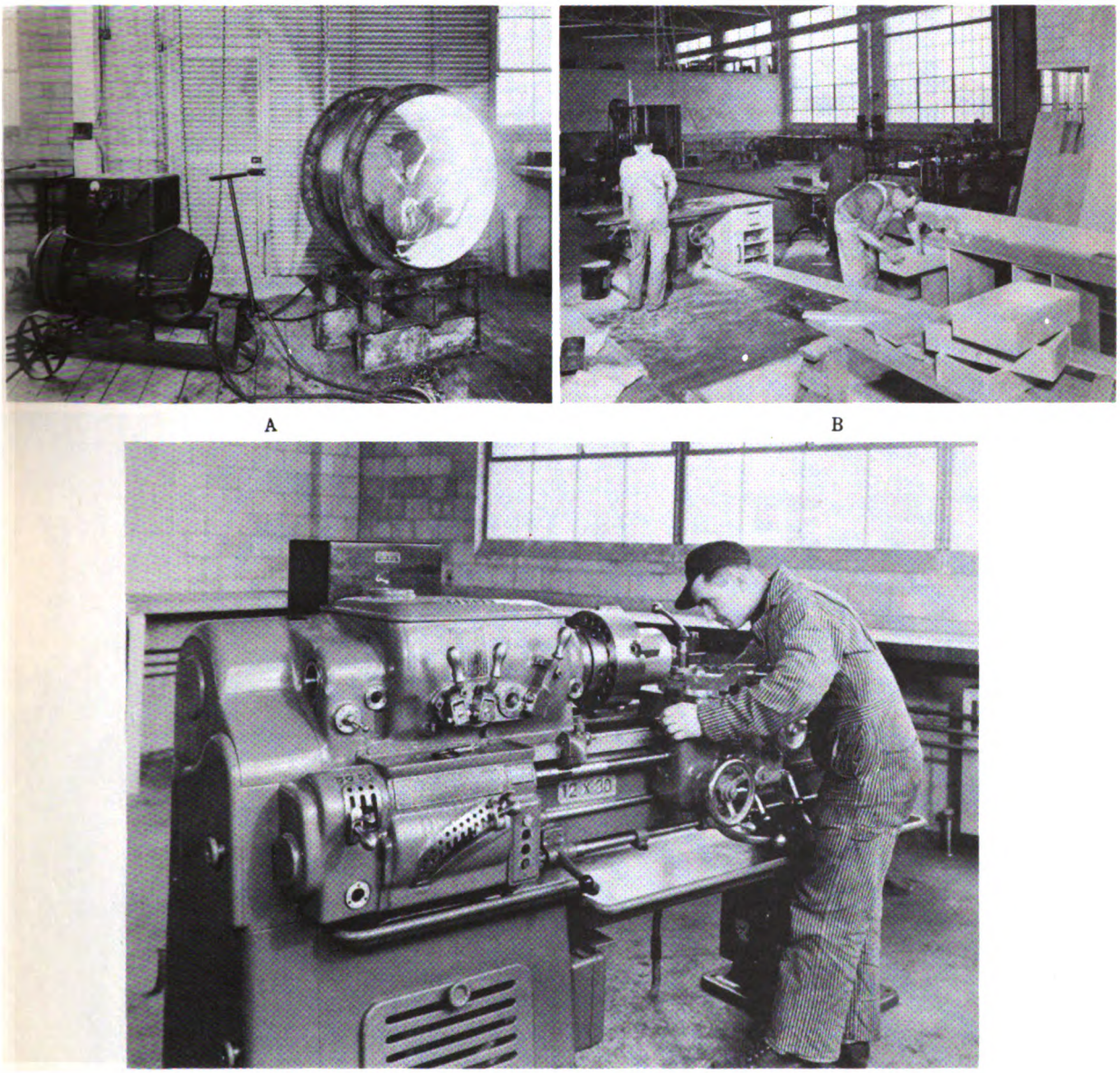

Figure 10.- A, Electric welding the converters; B, woodworking shop, while small, is well-equipped with necessary tools; C, a precision tool-room lathe.

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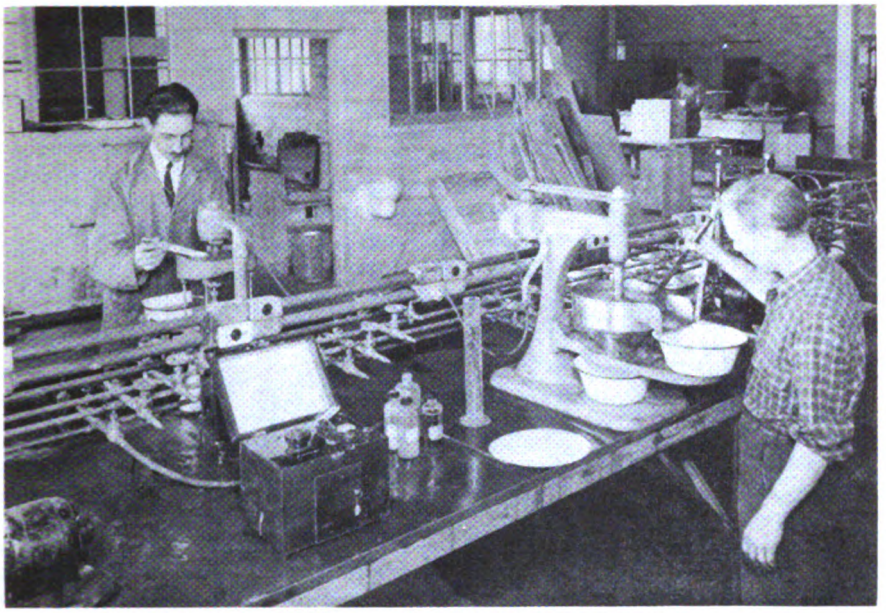
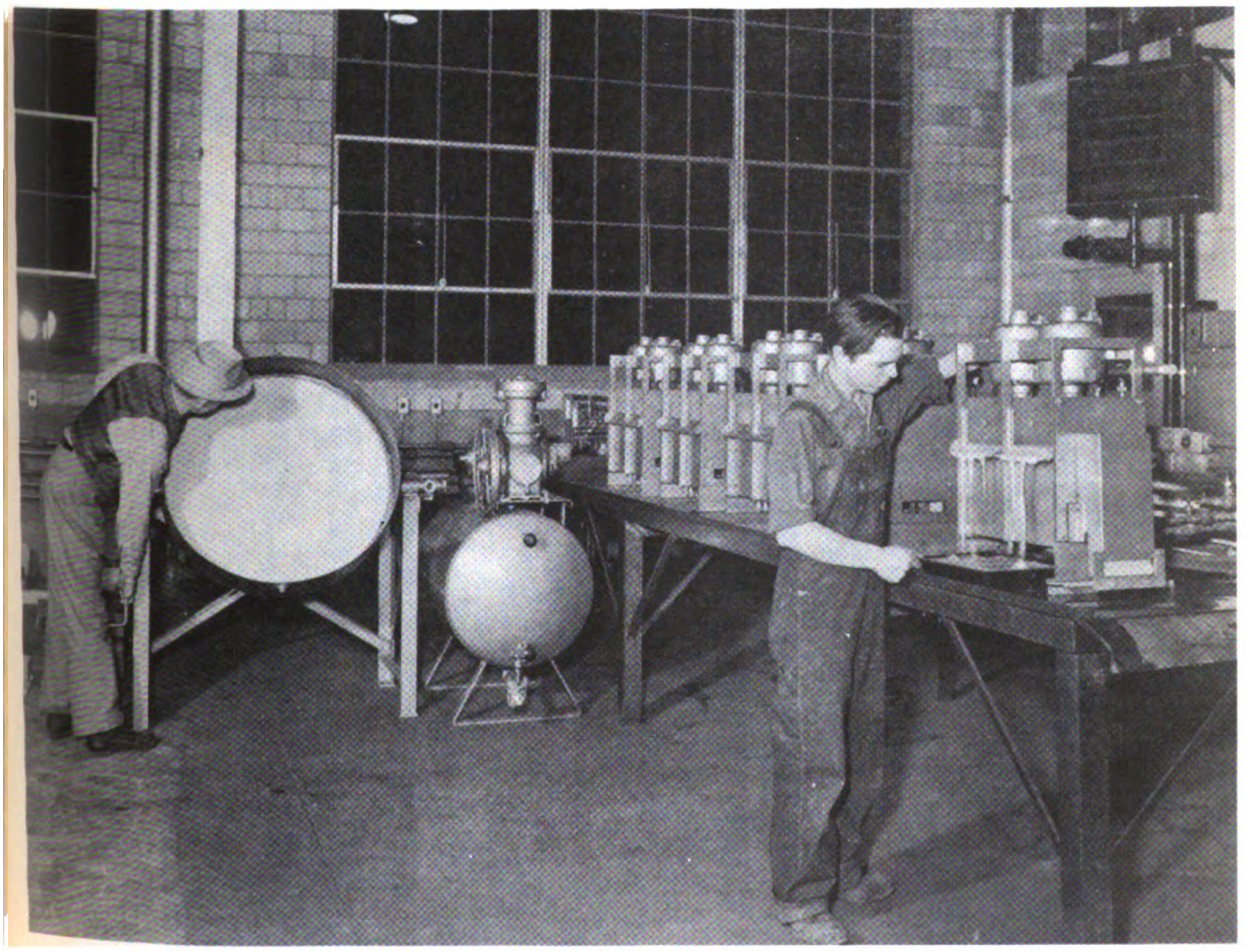


A



B

Figure 11.- A, Types of laboratory flotation cells; B, 6-cell flotation machine.

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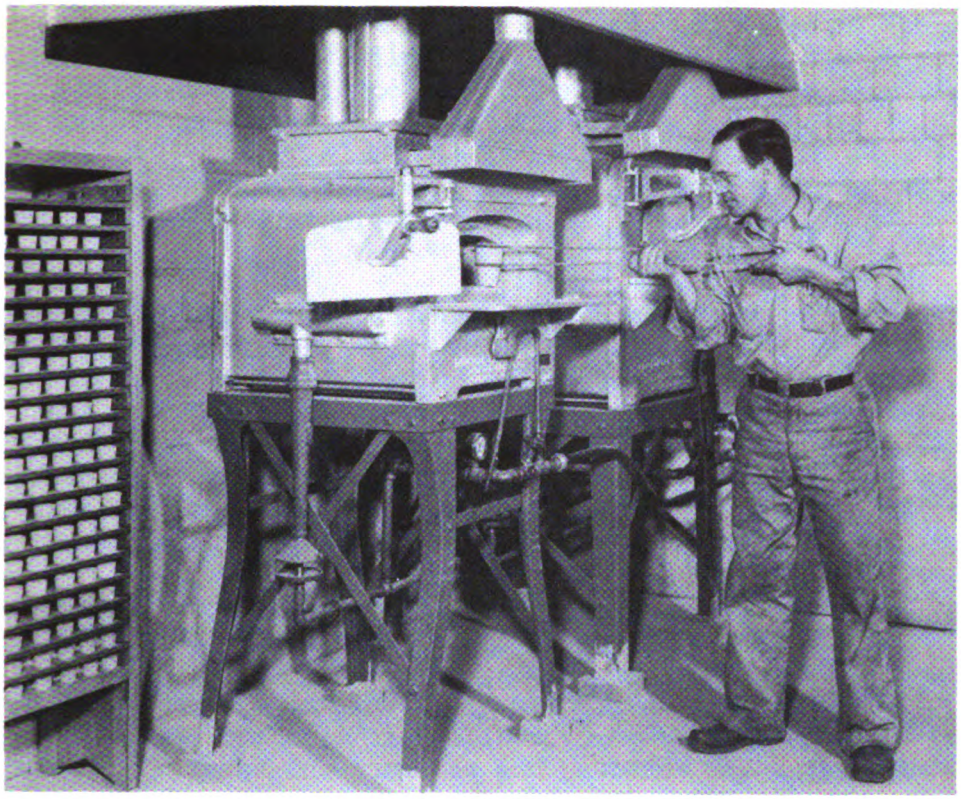

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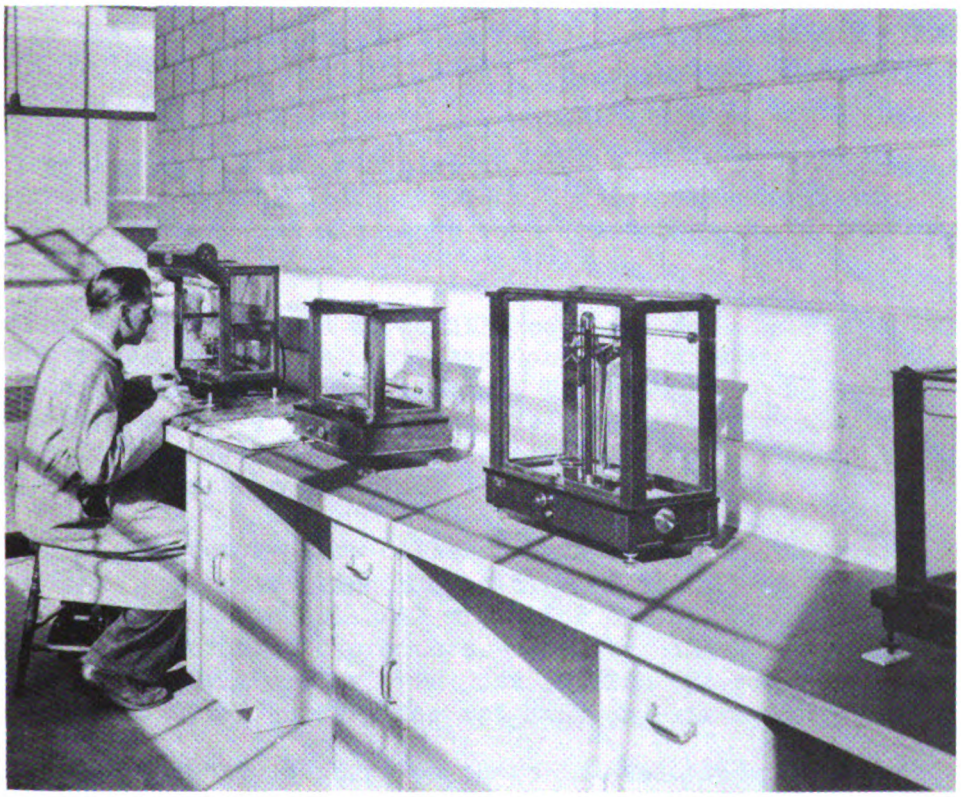

B

Figure 12.- A, Two gas-fired muffle furnaces provide the furnace equipment for fire assaying. B, Gold balances sensitive to a ten-millionth of an ounce.

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Besides these main tools, the shop has the necessary pedestal grinders d other auxilary equipment, including a drill press for rough work and a nch and shear, which has been found to be invaluable when constructing uipment from angles and sheets.

The shop has also complete welding equipment for oxyacetylene welding d cutting and a 400-ampere, single-operator, electric welding outfit ig. 10,A).

An instrument shop for precision work is separated from the remainder the shop by a glass partition. This shop is equipped with a precision ol-room lathe having a 12-inch swing and 30 inches between centers ig. 10,C). This lathe is capable of an accuracy of 2 ten-thousandths ch in 3 linear feet. Accuracy of this kind is important in making the rts of high-frequency oscillators and other physical equipment. The in-rument shop also has an 8-inch grinder and other small precision equip-nt required in making instruments for laboratory use.

In a tool-storage room adjacent to the instrument shop a complete supply small tools is kept for the use of the shops and laboratories.

A building like this one involves much carpentry work and cabinet king to supply shelves, benches, and cabinets, as well as bases for pecial instruments and forms for furnaces and patterns for castings.

The wood-working shop, while small, is equipped with the necessary achine tools so that the work may be done rapidly and efficiently (fig.10,B); hese include a 20-inch, tilting-arbor table saw, a 12-inch jointer, and 50-by 32-inch band saw.

The ore-dressing laboratory occupies the space south of the machine hop and is served by a 3-ton, overhead crane. This laboratory includes a hemical-control laboratory and a balance room, partitioned off from the rger area by glass.

The chemical-control room is especially equipped for rapid analyses of lotation products, especially by microscopy and colorimetry. The balance oom serves the assay as well as the chemical laboratory and is equipped ith gold balances, sensitive to less than one-ten-millionth ounce (fig.12,B). he ore-dressing laboratory has small scale equipment for flotation, magnetic eparation and electrostatic separation.

Three types of laboratory-size cells are available for flotation studies fig. 11, A and B). For controlling the acidity of the flotation pulps pH eters are available, as are small ball mills for conditioning and pressure ilters for rapidly filtering the products. Finally, there is an unusually arge and effective electric drying oven just outside the control laboratory, so that samples may be dried quickly for weighing and analysis.

For small-scale magnetic separation there is available a high-intensity, induced roll separator capable of separating such ordinarily nonmagnetic

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materials as biotite and quartz. There is also a small, tilted-belt, alternating-current magnetic separator of the type developed by the division's engineers. The small electrostatic separator is also of the alternating-current type and was designed and built by the division.

In addition to this small-scale ore-dressing equipment there is a complete mill on a large laboratory scale, made up of units that can be combined to give almost any desired ore-dressing circuit. Its essential units are a grinding mill, centrifugal pumps, a small concentrating table, a 5-product hydraulic classifier, an 8- by 7-foot thickener, a 14-inch by 8-foot rack classifier, a 2- by 3-foot agitator, a single-pocket sizer, a 12-by 12-inch jig, a vibrating screen, and a 6-cell flotation unit (fig.11,B This mill can produce several hundred pounds of products per day and will furnish data from which an actual pilot plant can be designed. There are also available two commercial magnetic-separator units, ehich may be included in the ore-dressing circuit where indicated.

The hydrometallurgy laboratory is completely enclosed to prevent fumes from injuring the metal-working and machine equipment. No fixed equipment is in the hydrometallurgy laboratory. Acidproof pumps, filters, and tanks are on hand to permit assembling hydrometallurgical circuits to suit any particular occasion. The roof over this room can be used for tanks if two levels are desirable. The fire-assay laboratory is also in this room. Two gas-fired muffles provide the furnace equipment (fig. 12,A). There are also available the usual cupel-making machines, flux and crucible storage, hot plates, and hoods for parting.

The pyrometallurgy laboratory is built with an especially high ceiling (40 feet). In it are installed a baghouse and a Cottrell treater. These ma be connected to a variety of metallurgical furnaces, which are set up in thi laboratory for the study of nonferrous metallurgical operations on a fairly large scale. These furnaces include a rotary kiln, a multiple-hearth furnace, a reverberatory furnace having a hearth 3 by 7 feet and fired by gas, and a converter 42 inches in diameter and 24 inches in length (fig. 13,A). Additional equipment of all types will be built in this room as required by investigational work under way.

In addition to this equipment for pyrometallurgical investigations, thi room houses the ore storage and preparation equipment for all the laboratori This equipment consists of a 9- by 7-inch jaw crusher (fig. 13,B), 8- by 10-inch rolls, vibrating screens, and a portable bucket elevator for delivering the crushed ore into the furnaces or onto conveyor belts which carry it into the ore-dressing laboratory.

In connection with this ore-preparation equipment there is installed an explosion-shattering machine. This type of rock-crushing equipment was designed by the division's engineers and depends on the explosive force of superheated water to disrupt the mineral particles. Work is under way to improve the design of this machine as well as to demonstrate its special value in the treatment of certain ores more fully.

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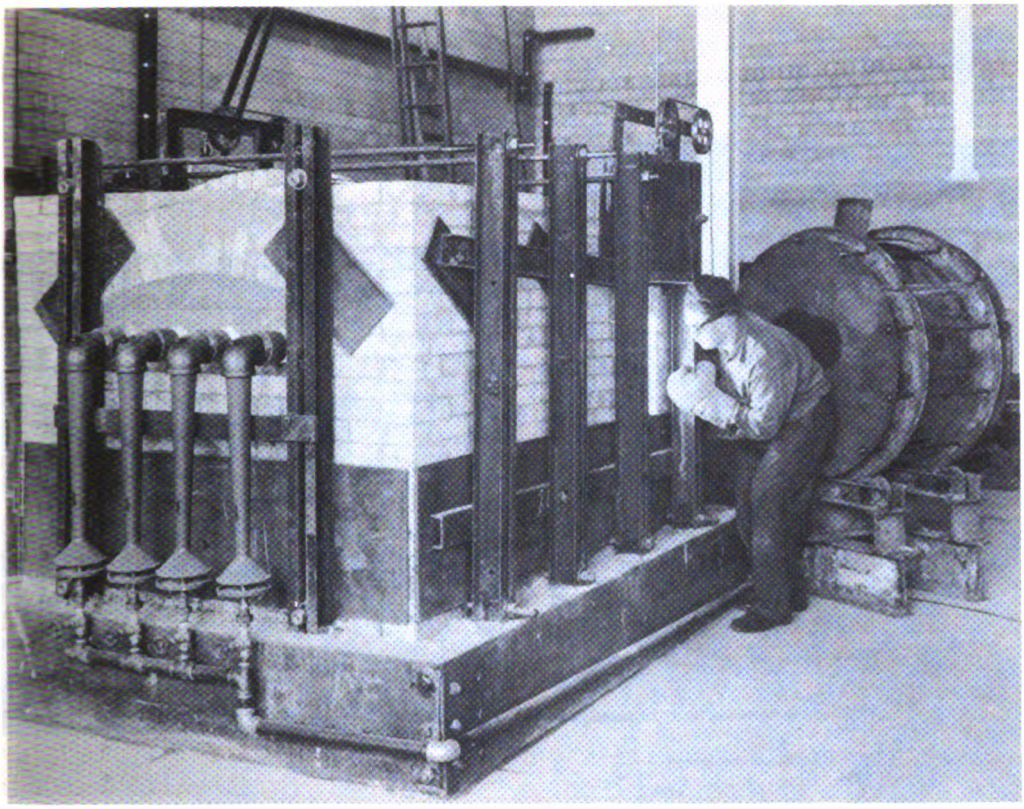

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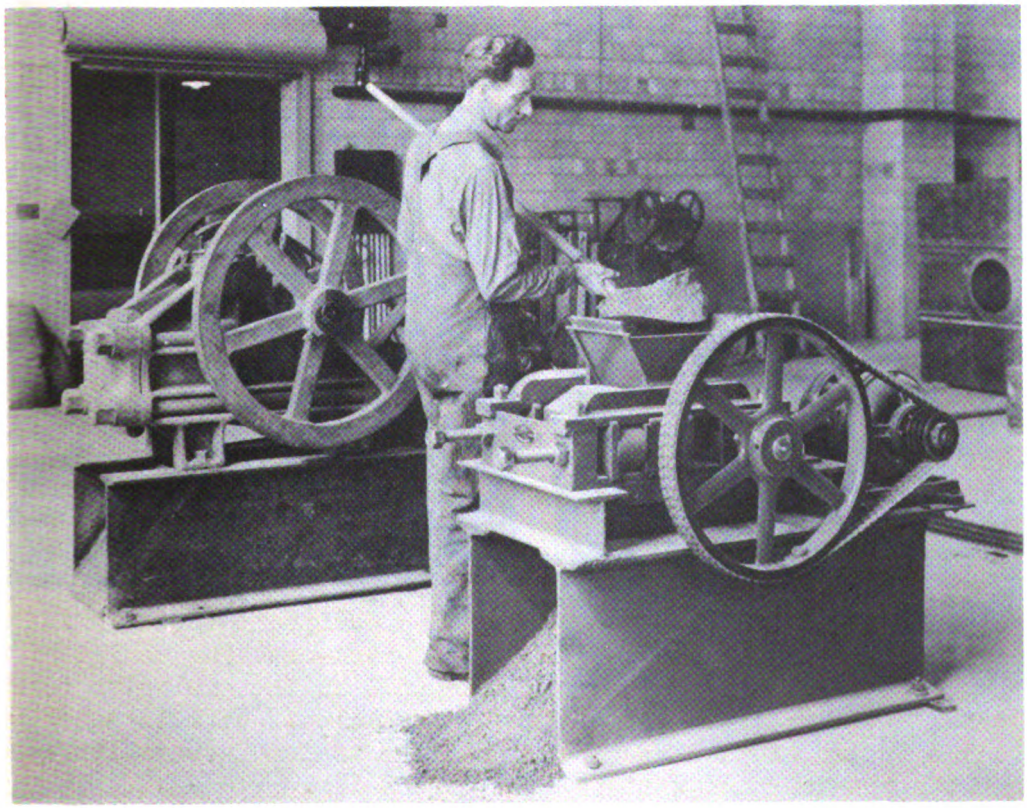

B

Figure 13.- A, Reverberatory and converter; B, jaw crusher and rolls.

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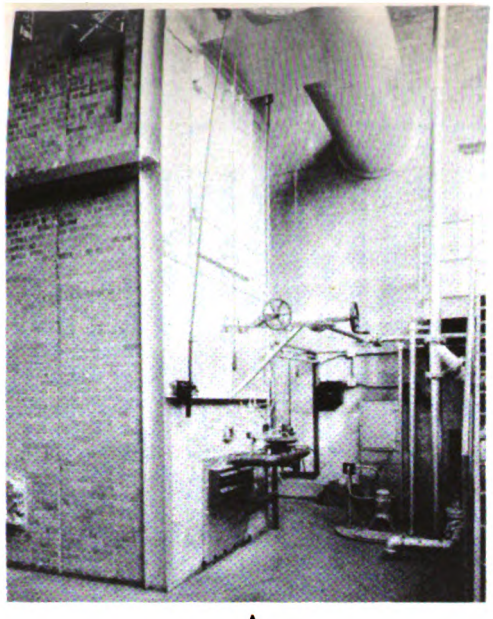

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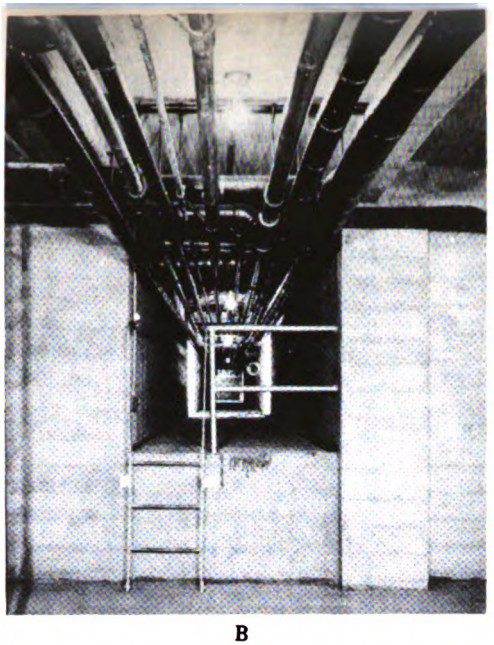

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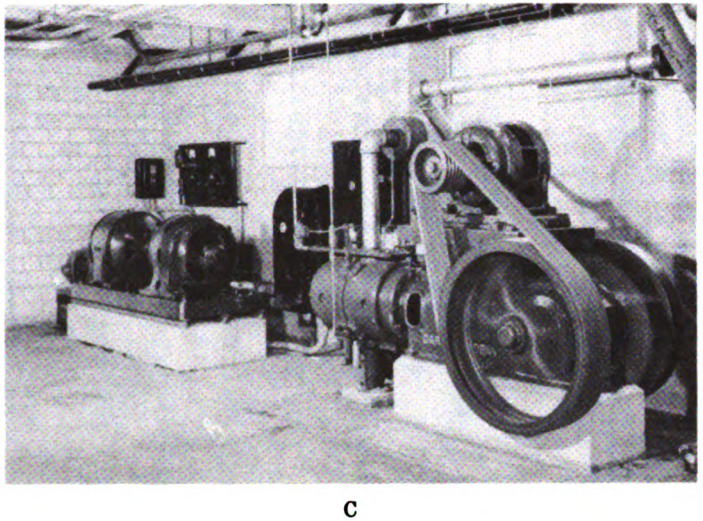

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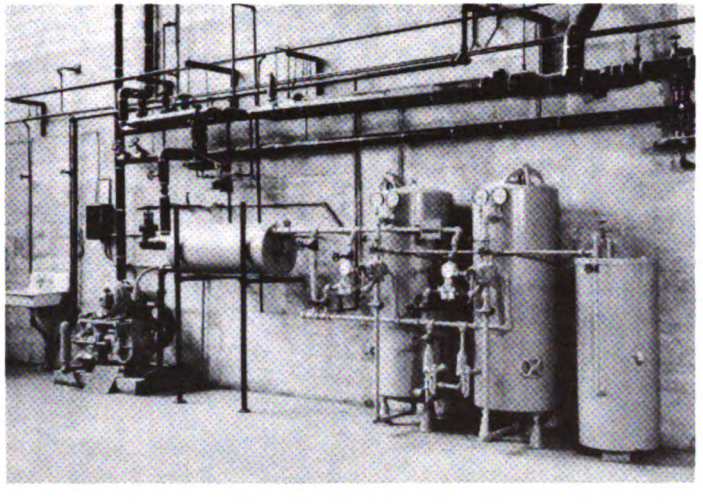

D

Figure 14.- A, A 150-horsepower boiler furnishes steam for heating and processing; B, the building was designed in two units. All pipe lines are in tunnels; C, an air compressor and motor generator provide service throughout both buildings; D, a water softener and high-pressure pump.

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Both units are served by steam at 10 and 450 pounds gage; air at 5 and 10 pounds gage; gas at 8 ounces and 25 pounds gage; electrical power at 220 volts, 3 phase, 60 cycles, and 115 volts, single phase, 60 cycles, with a capacity of 500 amperes in the three-story unit and 2,000 amperes in the single-story unit. Direct current at 250 and 125 volts, with 40 horsepower capacity is supplied to both units. Hot, cold, and conditioned water (fig. 14,D) is also available within both units. Steam is used for heating the three-story unit by direct radiation and the one-story unit by blower units.

The boiler room on the extreme east side of the three-story unit is equipped with a 150-horsepower, water-tube, sectional-header type of boiler operating on 450 pounds gage pressure (fig. 14,A). This unit is fired by gas, using an injector-type, automatically controlled burner. In addition to the boiler there are the following appurtenances: High-pressure, electric-driven, plunger-type boiler feed pump; water-softening equipment of zeolite type, having a capacity of 300 gallons per hour; and pressure-control equipment. Steam pressure is reduced in two steps for heating from 450 to 10 pounds. Steam is used at higher pressure for experimental work. The boiler room is connected by an underfloor passageway 7 feet high and 6 feet wide to the single-story and three-story unit.

On the south and west sides and adjacent to the boiler room are the garages for housing nine trucks and automobiles and an automotive repair shop.

Under the west end and extending the full width of the single-story unit is the service room, its size being 25 by 100 by 15 feet in height, into which the service passageways or tunnels containing the pipes and conduits (fig. 14,B) connect. This service room houses the following equipment:

1 telephone vault.
1 horizontal, motor-driven, single-stage air compressor, having a capacity of 300 cubic feet of air at 100 pounds gage per minute with automatic controls for operating continuously or intermittently (fig. 14,C).
1 40-horsepower, 125-volt, direct-current, motor-generator set with controls.
1 10-horsepower, 250-volt, direct-current, motor-generator set with controls.
1 main switchboard controlling electric service, both A.C. and D.C., to both buildings.
1 transformer bank partitioned off by fireproof walls, housing the transformer bank of 4-150 kv.a. transformers. This transformer bank is served by a 3-conductor underground cable at 4,000 volts.

The main switchboard serves the various unit breaker panel boards throughout both buildings and contains in addition circuit breakers for the equipment adjacent thereto.

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